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PHOTOMETRIC AND COLORIMETRIC CHARACTERISTICS OF CHEMILUMINESCENCE - CYALUME[R]

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This report presents an analysis of the photometric as well as the colorimetric characteristics of chemiluminescence-Cyalume[R]. It has been demonstrated that the chemical light offers advantages over other light sources because it generates light without thermal energy. It is suitable for situations where the use of conventional light could be hazardous. It works in all weather conditions and under water as well. On the other hand, its disadvantages include the relatively short lifetime of useful light, the poor color discrimination because of the narrow band spectral emission and a

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slight chromatic variation as a function of time. Nonetheless, it has potential military applications such as emergency lighting in aircraft, a guide for hoist missions, a set of helipor. markers, a ground guide, or a parachute locator.

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SUMMARY

This report investigates and analyzes the photometric as well as the colorimetric characterisitcs of chemiluminescence - Cyalume[R]. It has been demonstrated that the chemical light offers advantages over other light sources because it generates light without thermal energy. It is suitable for situations where the use of the conventional light could be hazardous. It works in all weather conditions and under water as well. On the other hand, its disadvantages include the relatively short lifetime of useful light, the poor color discrimination because of the narrow band spectral emission and a slight chromatic variation as a function of time. Nonetheless, it has potential military applications such as emergency lighting in aircraft, a guide for hoist missions, a set of heliport markers, a ground guide, or a parachute locator.

Robert W. Bailey

ROBERT W. BAILEY
Colonel, MSC
Commanding

Procedure - The light stick was placed 2 inches in front of the RSS. The slit width was 500 μm. The filter position was open and the vertical gain was set at 10X. The measurements were made at the initial breakage of the light stick and thereafter at 10 min, 20 min, 25 min and 30 min intervals. The DPO was then used to obtain the spectral power distribution of the light. The software-controlled CIE chromaticity computations were immediately obtained. The results were graphed from the DPO to a Tektronix teletype (TTY) CRT display and printed out from a Tektronix hardcopier.

RESULTS

a. Photometric Measurement

Figures 1 and 2 show the average values of luminance and illuminance respectively. The average value of luminance measured about one minute after activation was 42.66 foot-lamberts. After three hours, this brightness level dropped to an average value of 3.78 foot-lamberts. Thus, about 91% of the original brightness was lost in three hours.

The average value of the illuminance measured about one minute after activation was 2×10^{-2} foot-candles. This illuminance level dropped in three hours to an average value of 17.35×10^{-4} foot-candles. The loss in original illuminance in three hours was equal to the loss in luminance, about 91%.

Measurements of one light stick after twelve hours showed that only 1.10% of the original luminance and only about .60% of the original illuminance remained. Readings taken from another light stick after twenty-four hours showed that only about .30% of the original luminance and only about .23% of the original illuminance remained.

b. Colorimetric Measurement

Figure 3 shows the power spectral distribution of the light stick right after the breakage of the light stick. It is noticed that the shape of the spectral distribution does not change in any considerable amount from 0 to 10 minutes. The subsequent three figures (Figures 4, 5 and 6) show the power spectral distributions of the light stick at 20, 25, and 30 minutes thereafter. Although in those figures, the unit in the abscissa is always the wavelength from 400 to 800 nm, the unit in the ordinate is 50 pw per division in Figure 3 and is 100 pw/div in Figures 4, 5 and 6.

The CIE chromaticity diagrams of the respective measurements are shown in Figures 7 through 10. The X and Y are the chromaticity coordinates. Z value in each case is also shown on the top of each figure. The arrow indicates the location of the light source within the CIE diagram.

DISCUSSION

Because the two components in the Cyalume[R] are temperature dependent, the brightness of the light is also varied with the ambient temperature. The reaction proceeds more rapidly with higher ambient temperatures. The light is also brighter with higher temperatures; however, the duration of light is proportionally shorter. All measurements were taken at a room temperature of 25°C, which was held reasonably constant.

Besides the temperature, the position of the light stick being measured could also influence the readings. Two of the light sticks were placed in a horizontal position to the photometer, while one was placed in a vertical position. The initial photometric measurements of the average of the two horizontal lights sticks were 35.7% less than those of the vertical light stick.

Another factor affecting the readings was the position on the light stick on which the photometer was centered and focused. Rapid successive readings along different points of the light stick yielded this information. Readings were highest in the middle and were lowest near both ends of the stick. In the horizontal position the difference in readings between the middle and end positions was about 32.8%. This difference in the vertical light stick was about 33.1%.

The spectral composition of the light did not change from 0 to 10 minutes (Figure 3). After ten minutes, the composition changed (Figures 4,5, 6). This change is reflected in Figures 7,8,9, and 10 in which the location of the light on the CIE diagram shifted toward the spectral locus (i.e. became more saturated). Table 1 summarizes the change of X and Y values. The percent change of X value was about 6% for the 20 minute measurement and 11.6% thereafter. On the other hand, Y value changed from 12.5% up to 15% and back down to 12.5%. The results were well correlated with the movement of the steepest change in the luminance measurement shown in Figure 1. It was also noticed that the spectral peak was shifted from 510 nm to 520 nm. Several theoretical interpretations have been speculated, but we do not intend to make any definite or plausible suggestion in this report.

CONCLUSION AND SUMMARY

Chemical light offers many advantages over other light sources because it generates light without thermal energy. It is suitable for situations where the use of conventional light could be hazardous. It works in all kinds of weather and under water as well. It is small, light in weight, easy to store and carry.

On the other hand, it has some disadvantages over other light sources. The Cyalume[R] chemical light sticks gave about three hours of useful light. About 91% of the original luminance and illuminance was lost after three hours. Maximum intensity occurred in the first fifteen minutes, decreasing rapidly thereafter. In short, it offers a restricted duration of useful brightness. The narrow band of spectral emission offers very poor color discrimination. Furthermore, the chromatic characteristics alter slightly as a function of time.

Currently, we do not know the shelf life with respect to the luminance, the emission spectrum and the ambient storage temperature. Information released by the company states that the shelf life is from six months to one year for the old type of Cyalume[R] and longer for the new type. Further field study on visibility of heliport emergency markers, luminance of ground signal markers in NOE flight, and on other potential applications are being suggested.

REFERENCE

The photometric portion of this report has been documented in USAARL-LR-76-5-7-4 (1975). Test samples have been generously supplied by American Cyanamid Company, Organic Chemical Division, Bound Brook, N. J. 08805.

TABLE 1 - X, Y values as a function of time

	Time 0-10 Min.	20 Min.	25 Min.	30 Min.
X	0.2311	0.2451	0.258	0.258
ΔX		0.014	0.027	0.027
%		6.06%	11.6%	11.6%
Y	0.6252	0.7035	0.7201	0.7034
$\angle$Y		0.078	0.095	0.078
%		12.5%	15.2%	12.5%

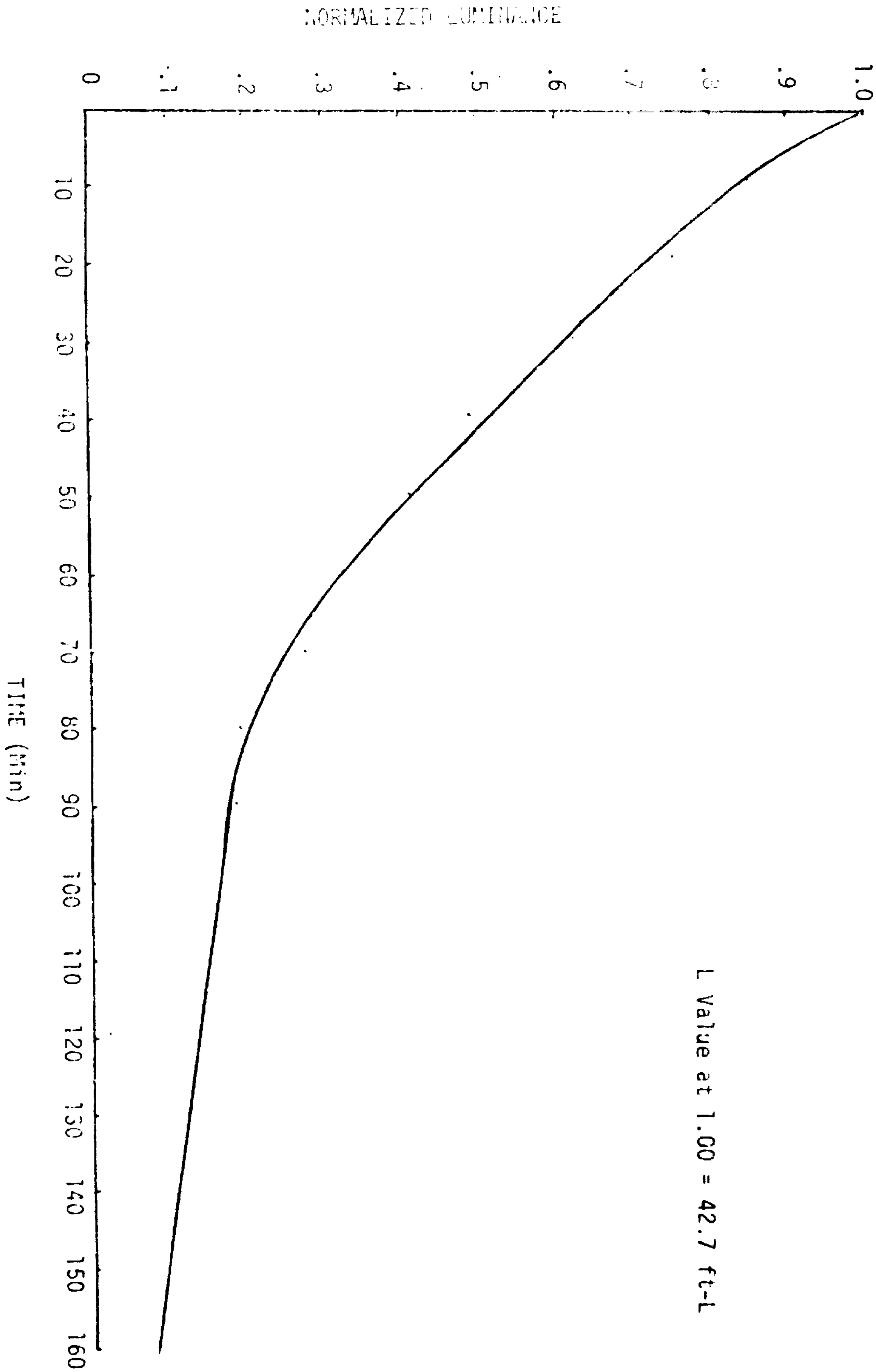

FIGURE 1. NORMALIZED (AVERAGE) LUMINANCE CURVE

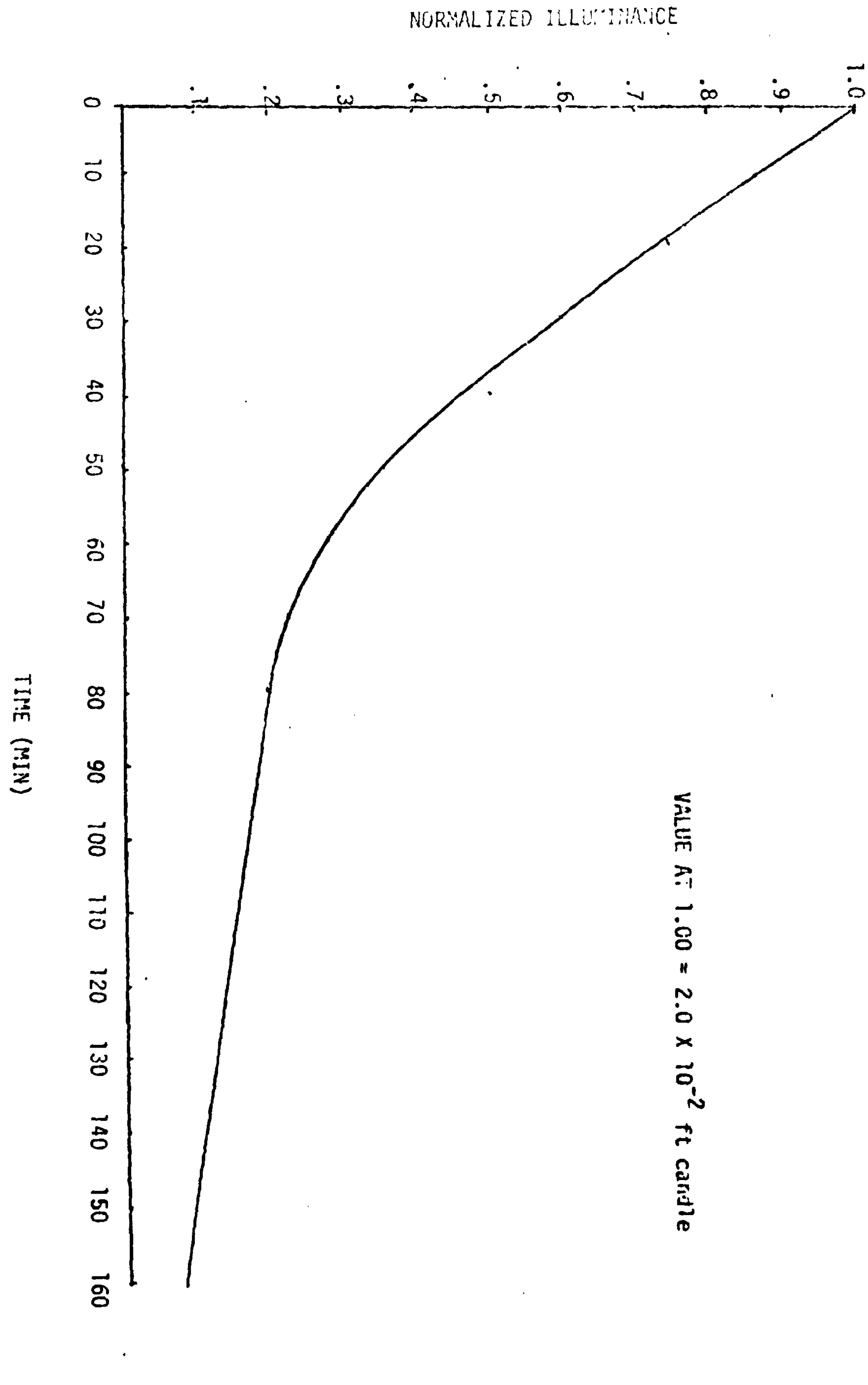

FIGURE 2. NORMALIZED (AVERAGE) ILLUMINANCE

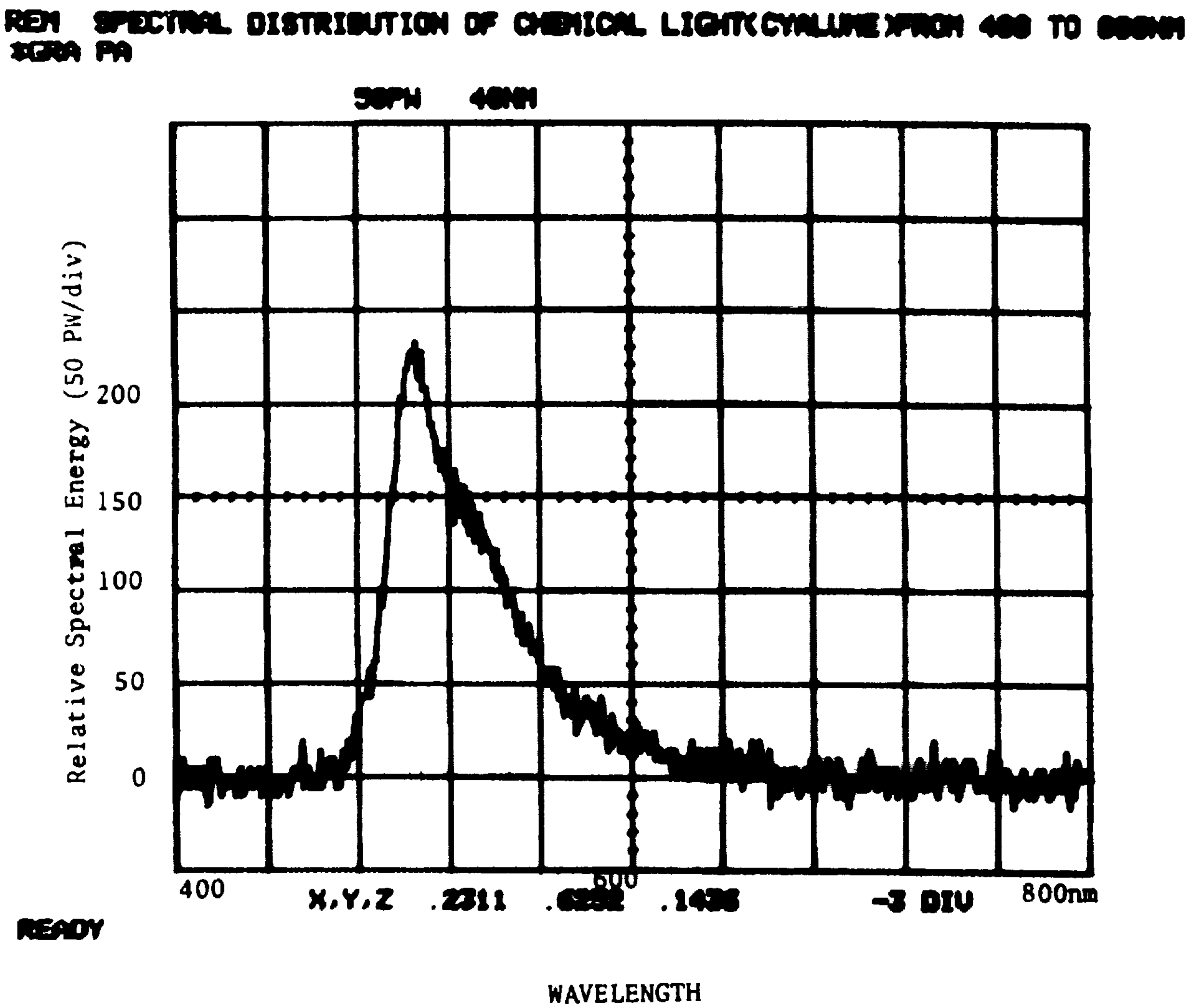

FIGURE 3. Power spectral distribution at 0-10 min.

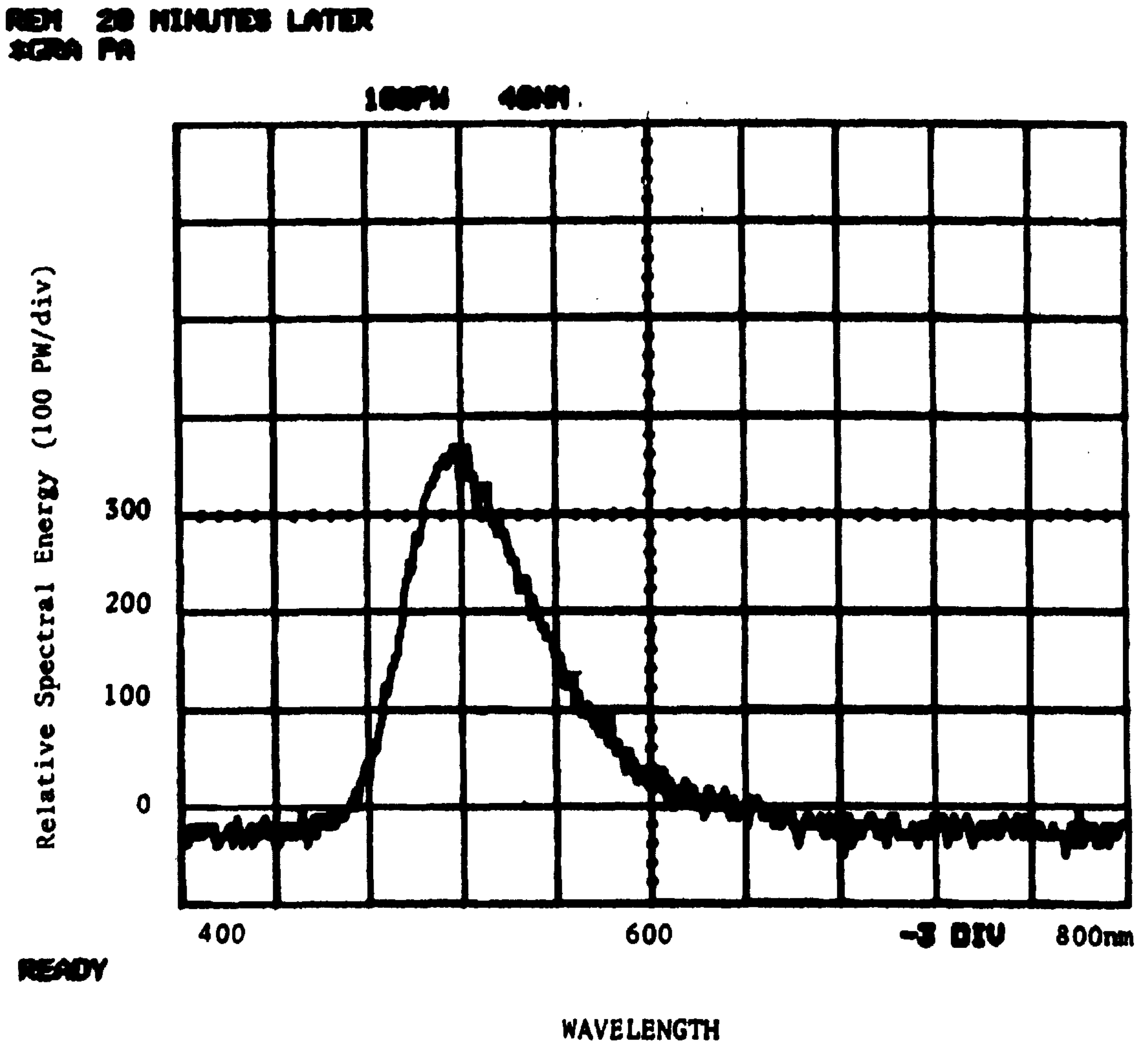

FIGURE 4. Power spectral distribution at 20 min.

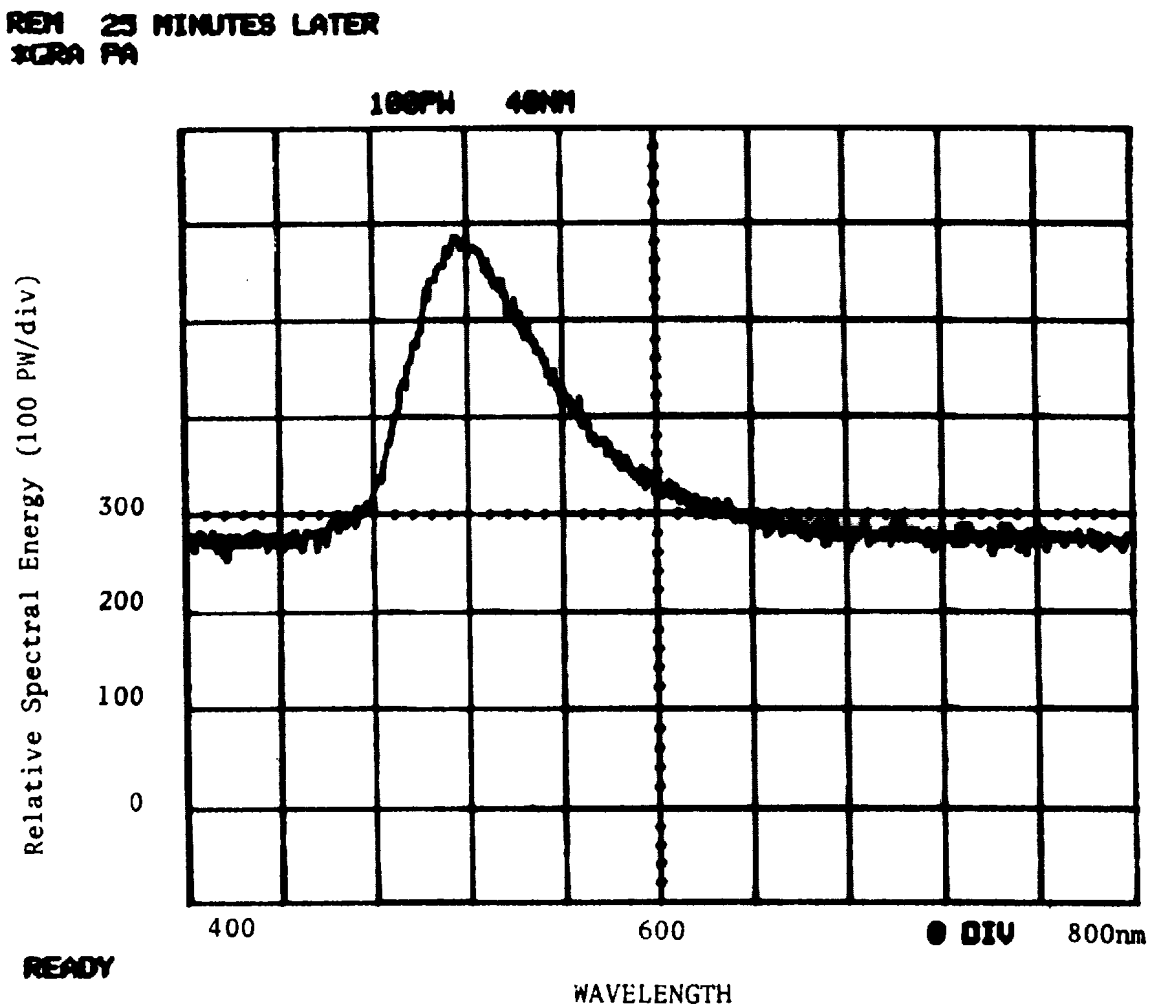

FIGURE 5. Power spectral distribution at 25 min.

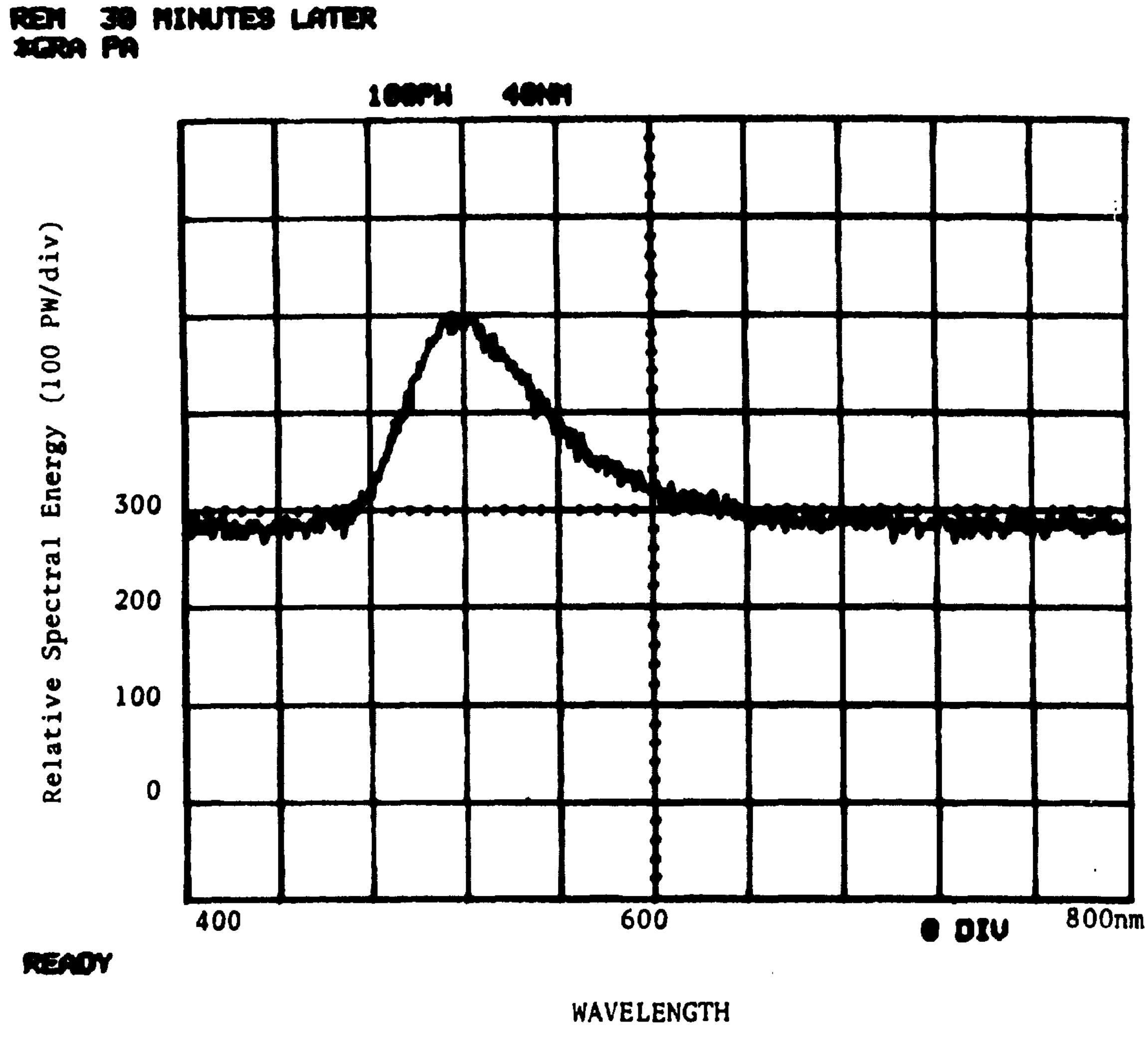

FIGURE 6. Power spectral distribution at 30 min.

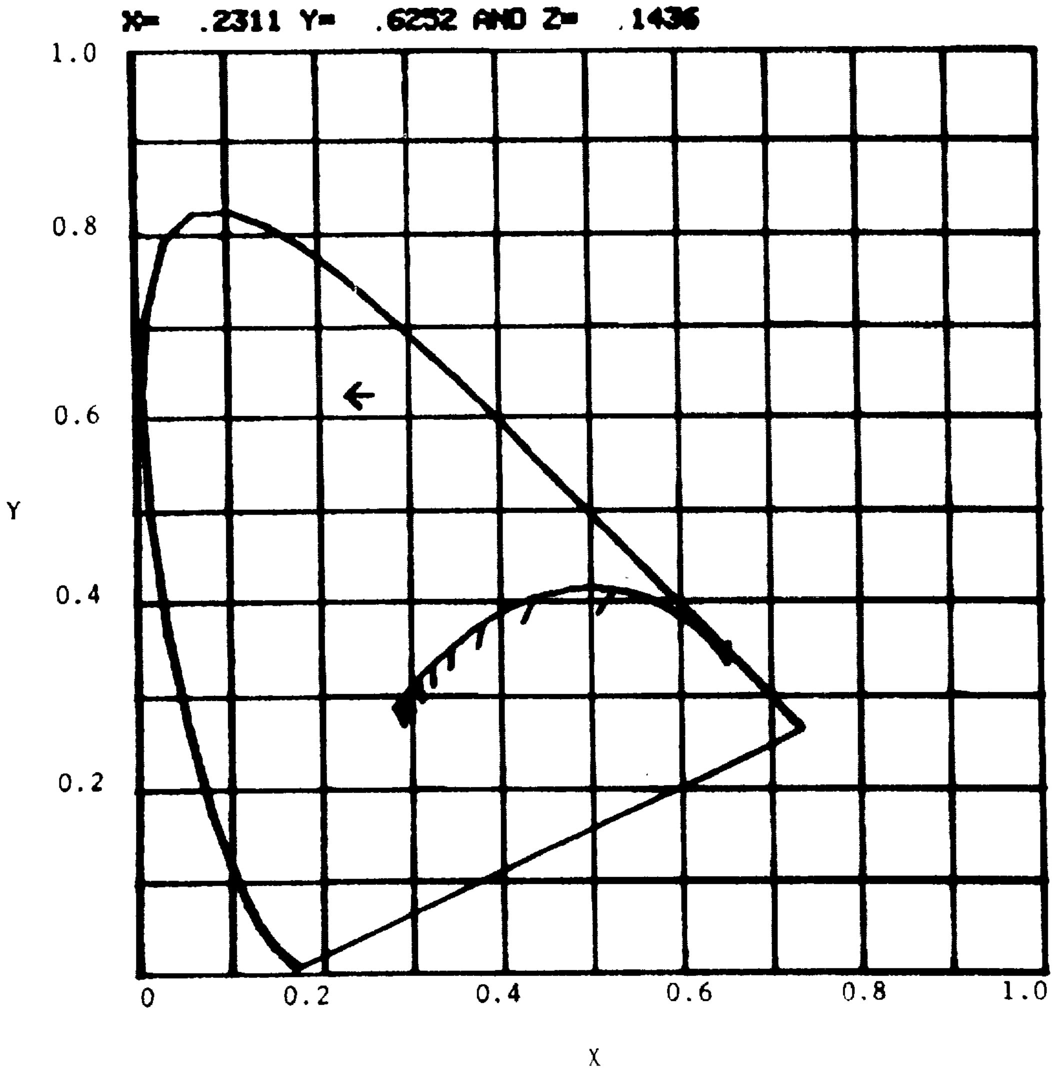

FIGURE 7. CIE Chromaticity Diagram of Figure 3

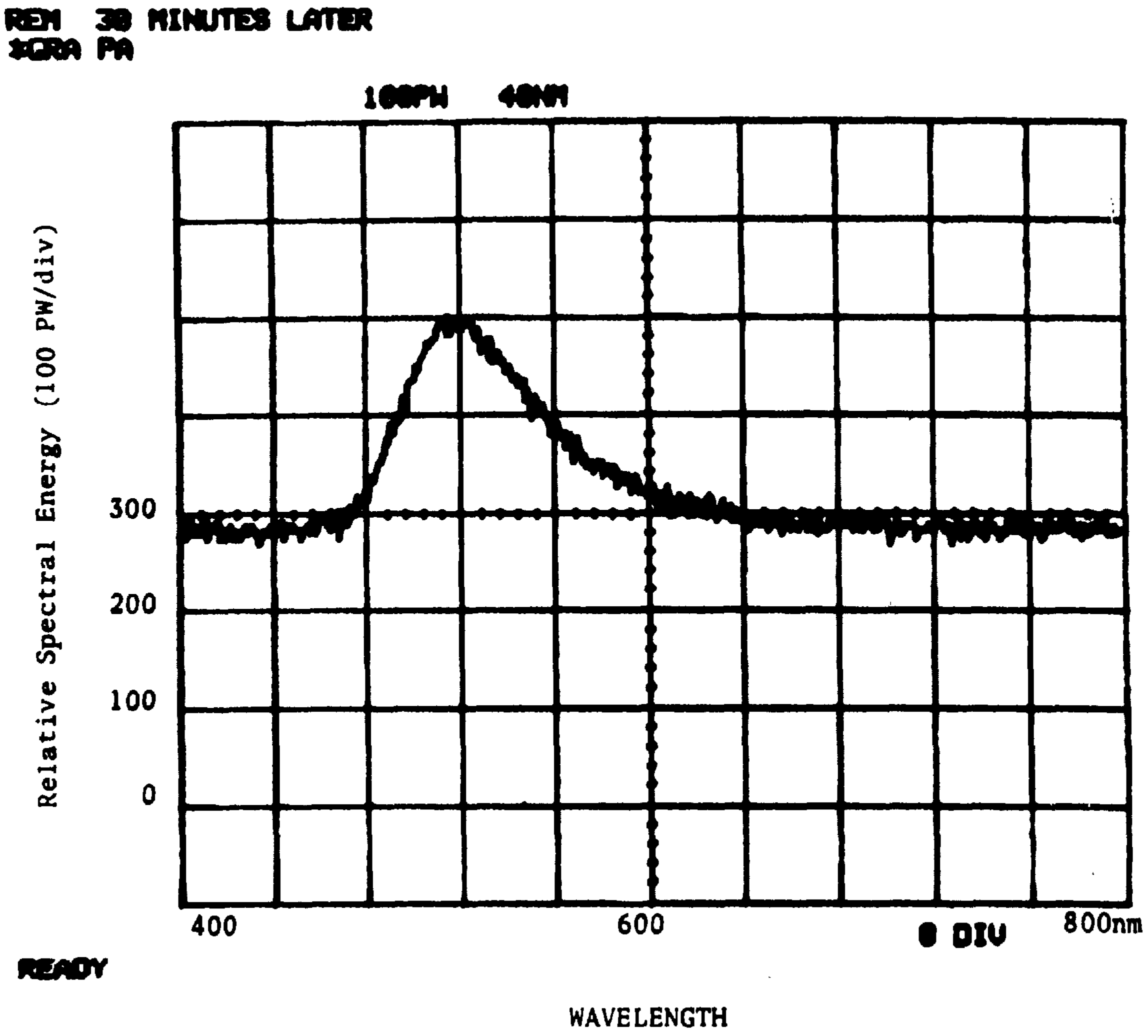

FIGURE 6. Power spectral distribution at 30 min.

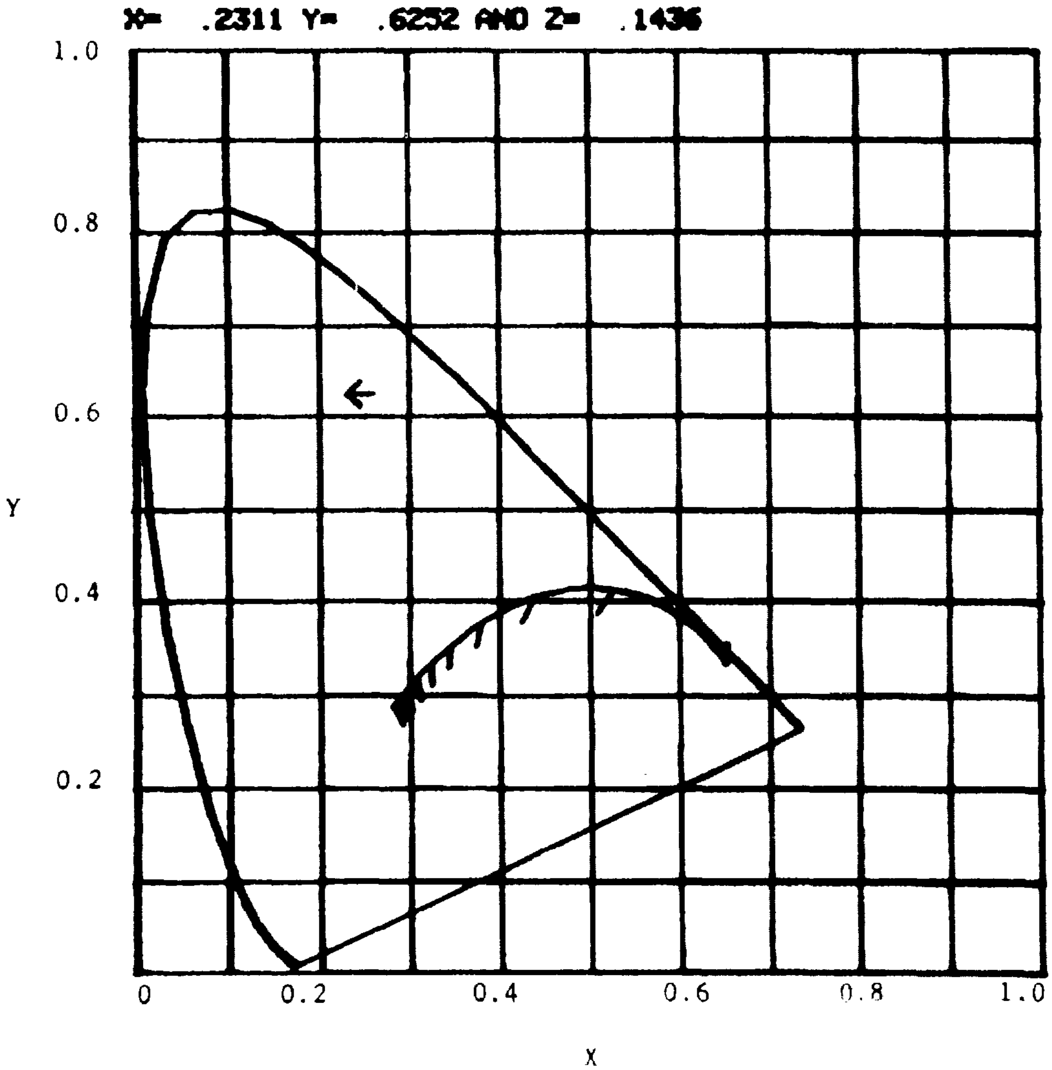

FIGURE 7. CIE Chromaticity Diagram of Figure 3

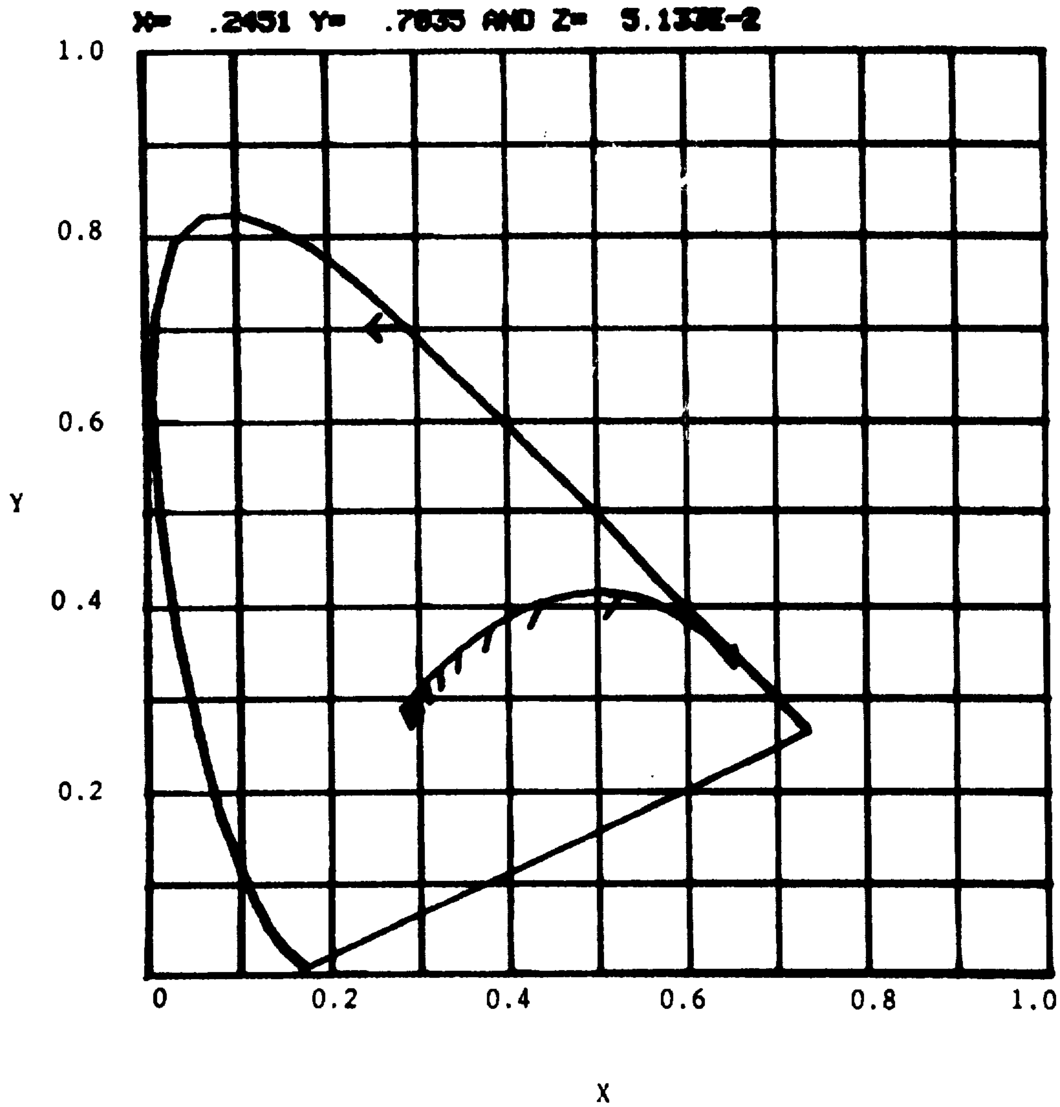

FIGURE 8. CIE Chromaticity of Diagram of Figure 4

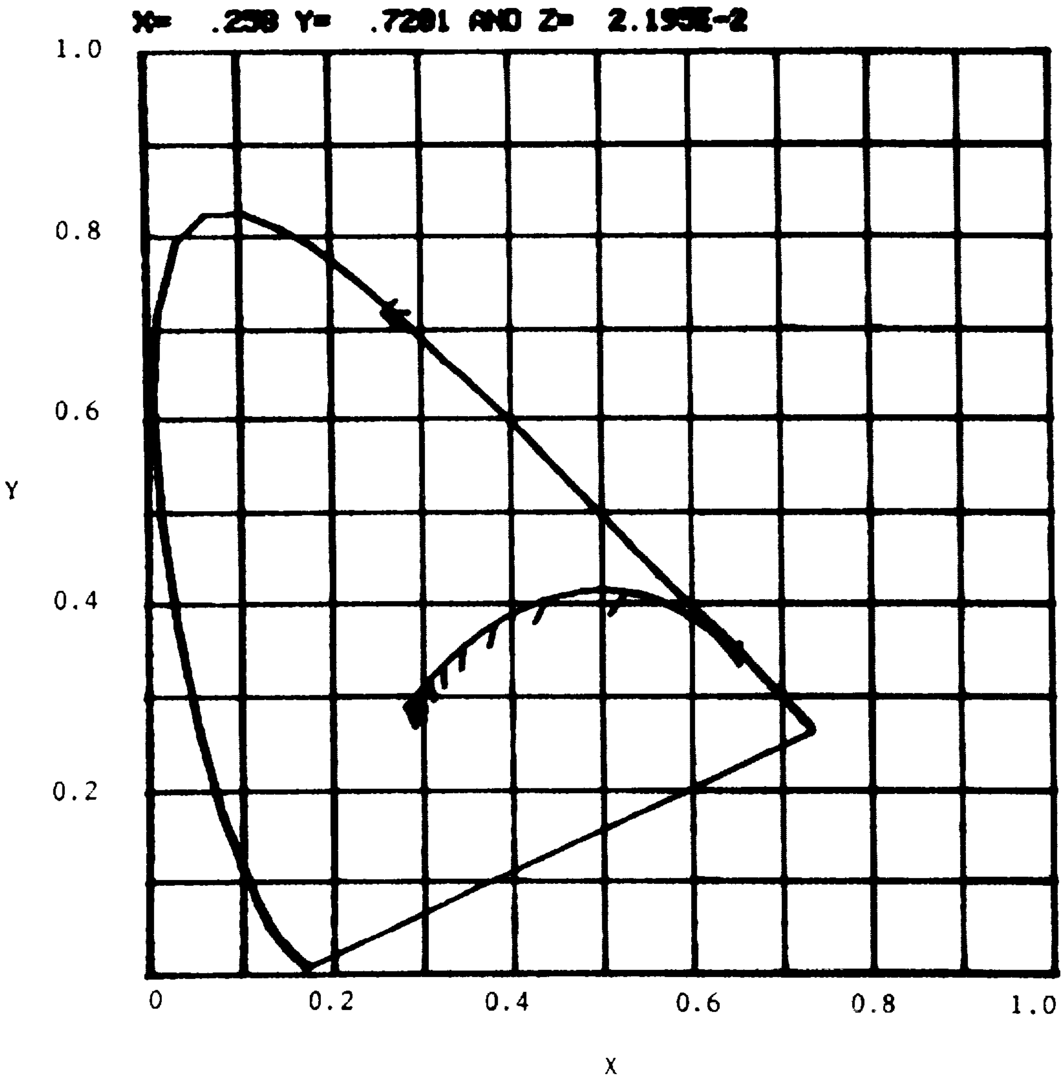

FIGURE 9. CIE Chromaticity of Diagram of Figure 5

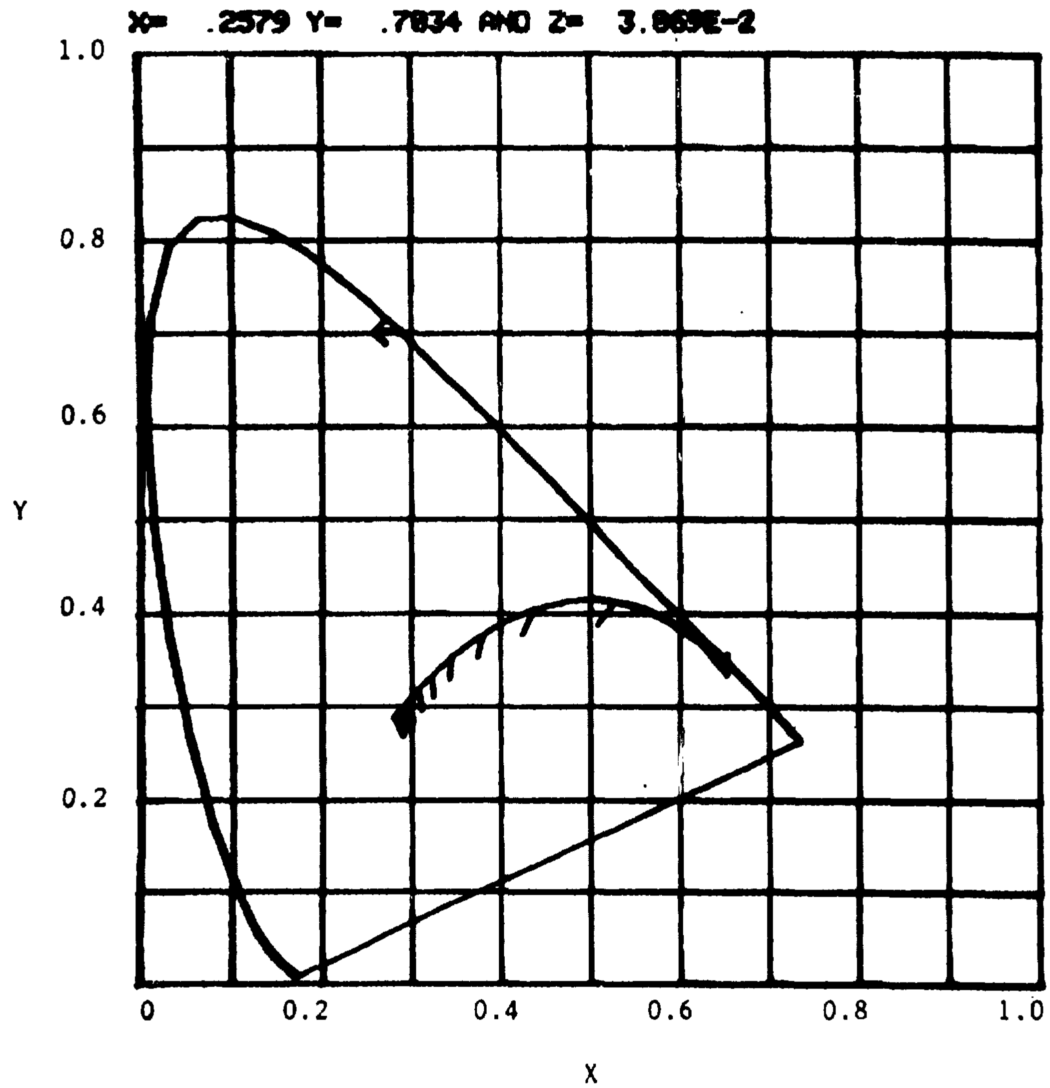

FIGURE 10. CIE Chromaticity Diagram of Figure 6